

Case-Based Reasoning to Enhance Diagnosis and CSP Model Debugging in Interoperability Testing: ADIOP

Mohammed H. Sqalli
sqalli@ccse.kfupm.edu.sa
Eugene C. Freuder
e.freuder@4c.ucc.ie

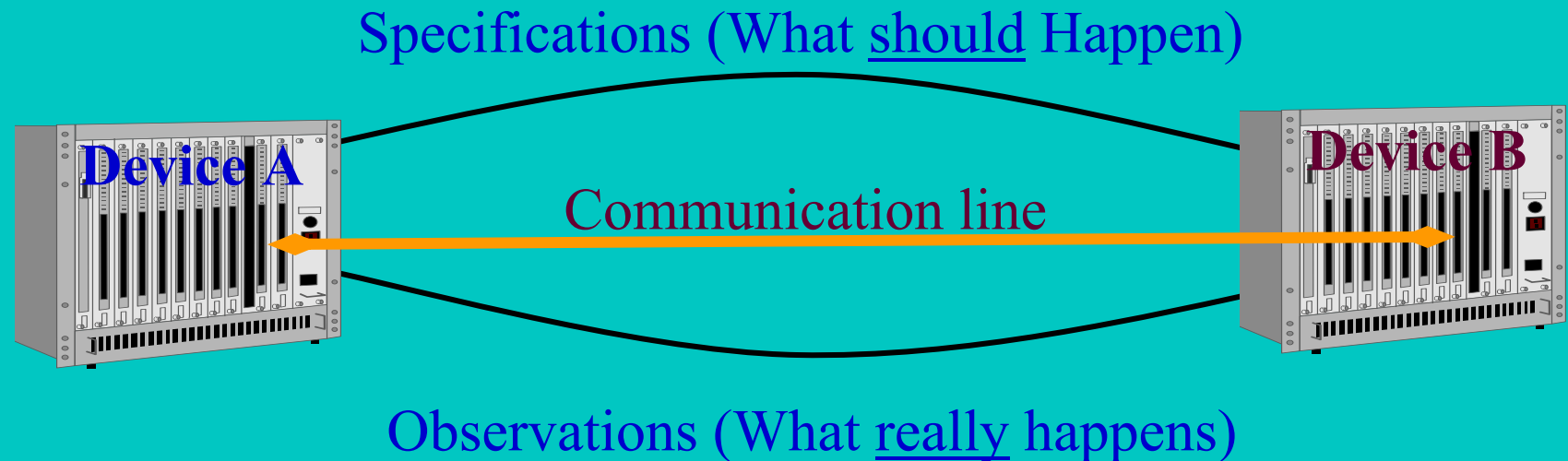
This material is based in part on work supported by King Fahd University of Petroleum & Minerals, Science Foundation Ireland, and the National Science Foundation. Some of this work was done while both authors were at the University of New Hampshire.



Outline

- Overview & Example
- Motivations
- CBR/CSP Integration
- Updating CSP Models
- Improving Explanations
- Evaluation
- Summary

Interoperability Testing



Interoperability Testing \Leftrightarrow Compare (Specifications, Observations)



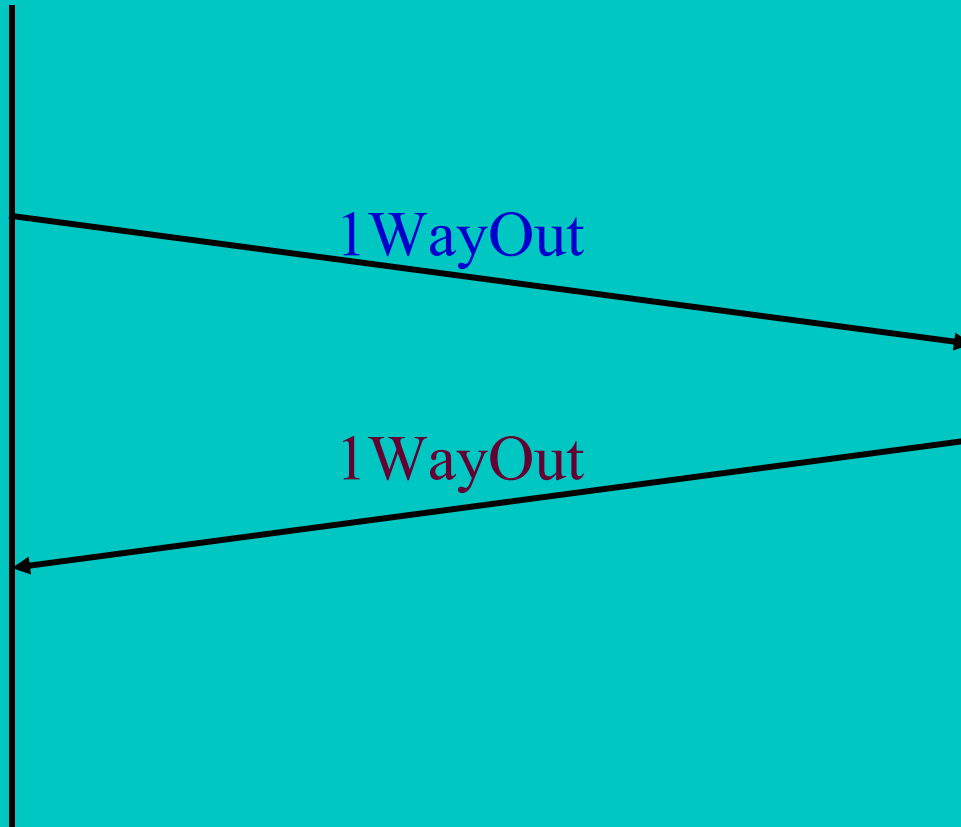
Example from a Test Suite

- Test Case ID: V4202H__004
- Test Purpose: Verify that the first Hello sent from both sides contains Remote node ID and Remote port ID set to zero (1Way).
- Pre-requisite: Both SUTs (A, B) are in **different lowest level peer groups** (Out).
- Verdict Criteria: The first Hello packet observed from each SUT will have the **Remote node ID** field and **Remote port ID** field set to zero (1WayOut).

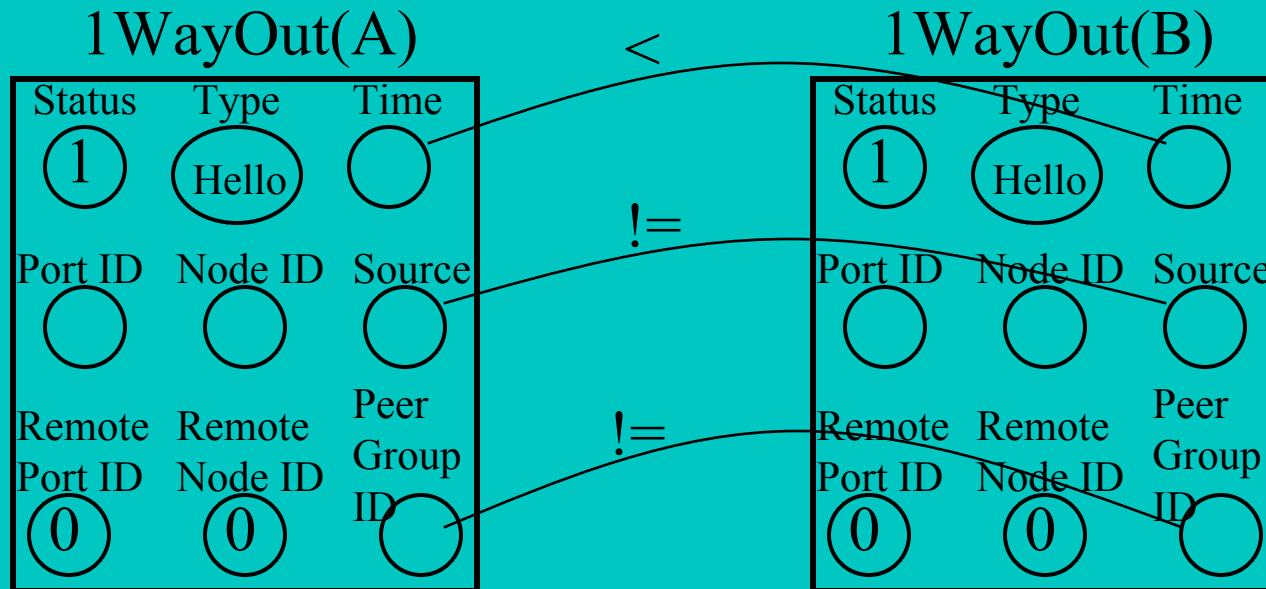
Example - Test Description

Switch A

Switch B

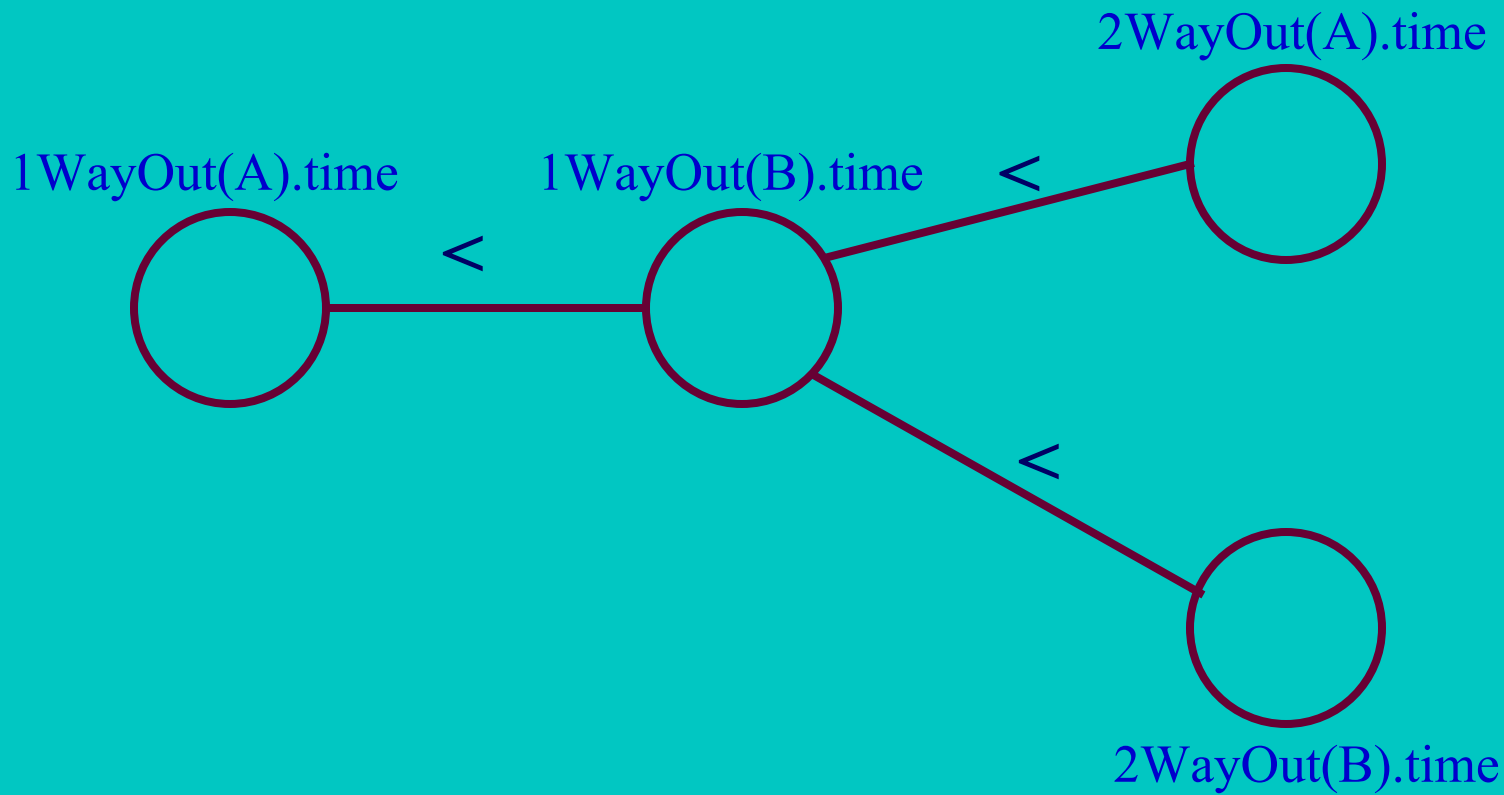


Example - CSP Model

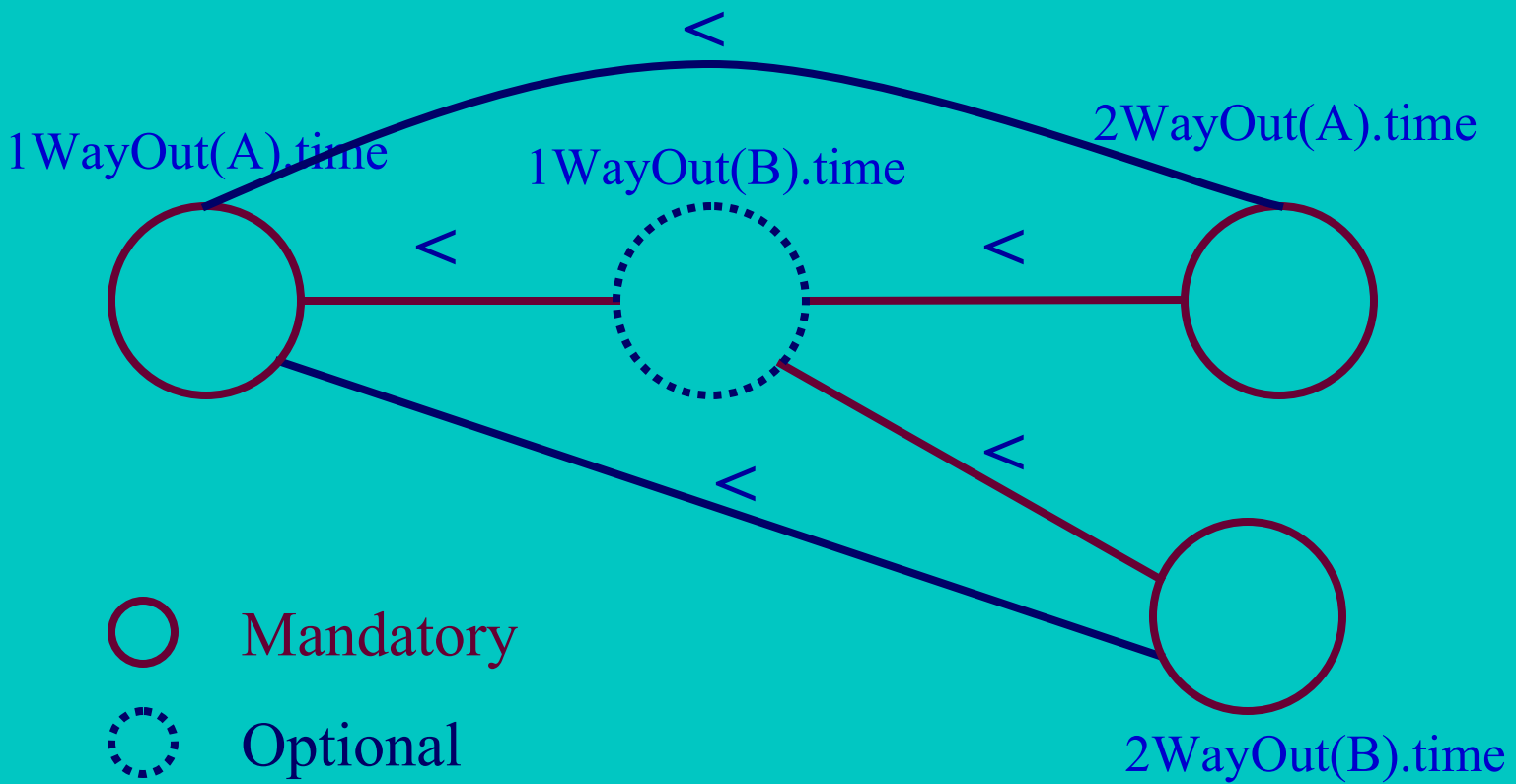


| | | |
|--------------------|---------------|--|
| Variables | | 1WayOut(A) {Source, Time, Status, Node_ID, ...} 1WayOut(B) {Source, Time, Status, Node_ID, ...} ... |
| Constraints | Unary | 1WayOut(A).Status = Mandatory 1WayOut(A).Remote_Node_ID != 0 |
| | Binary | 1WayOut(A).Time < 1WayOut(B).Time 1WayOut(A).Peer_Group_ID != 1WayOut(B).Peer_Group_ID ... |

CSP Model (Time Constraints)



CSP Model Updated

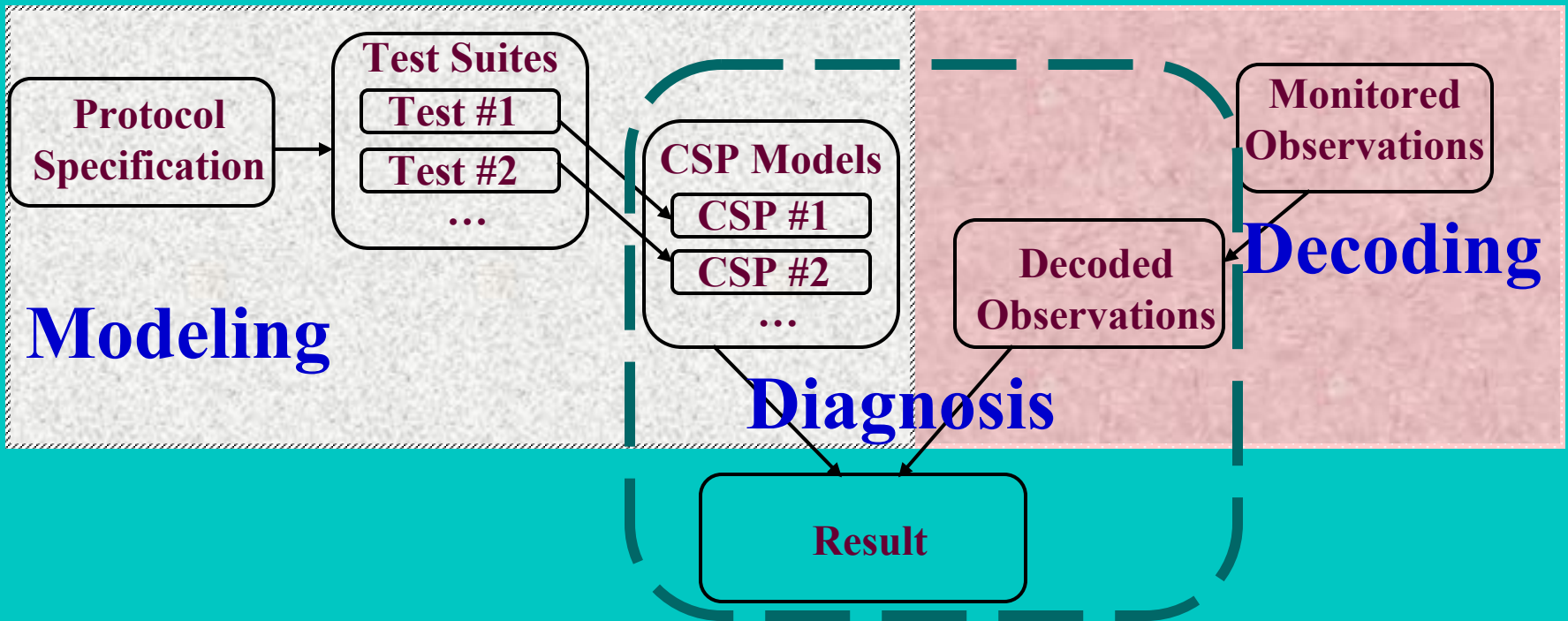




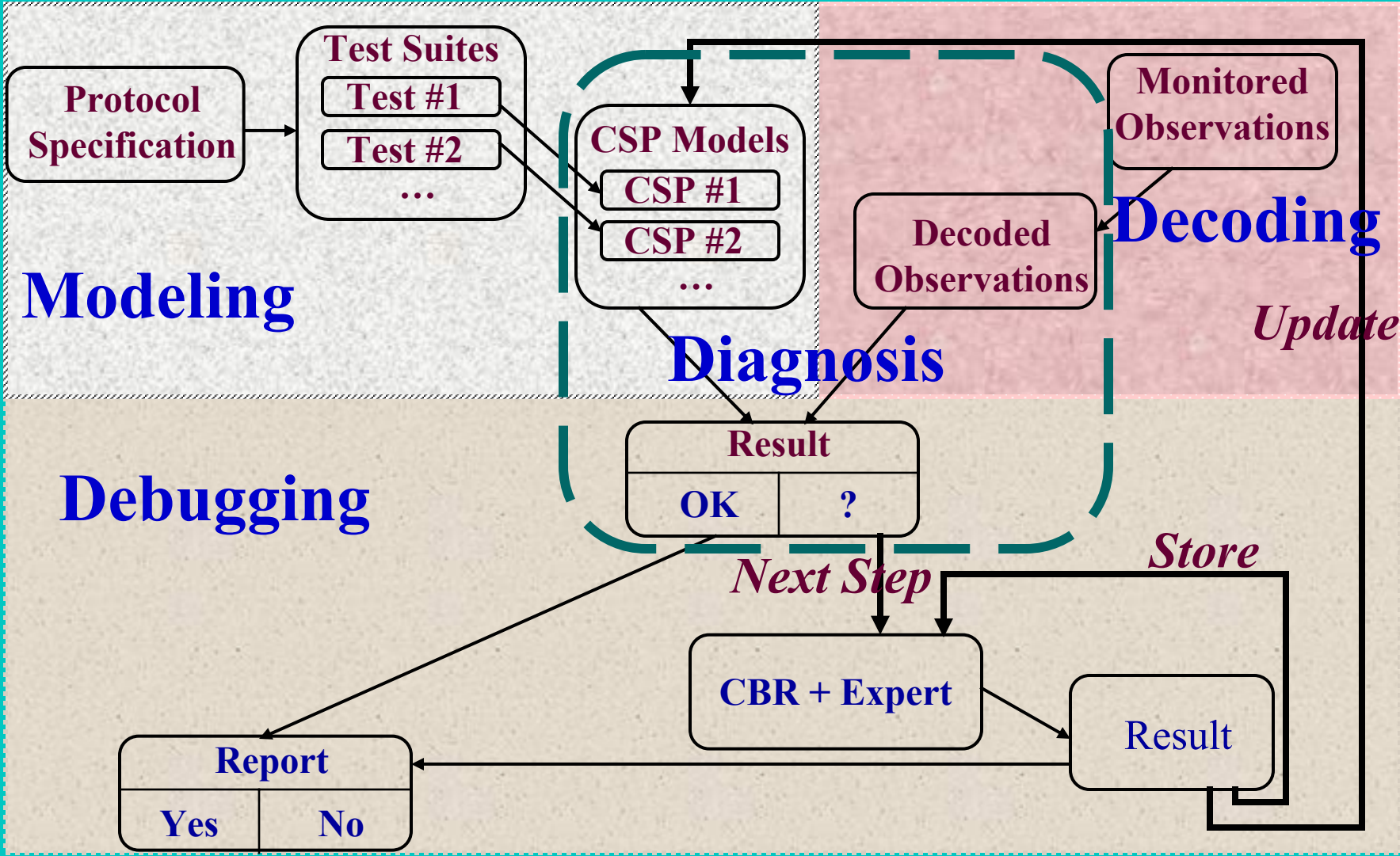
Rules for Updating this CSP Model

- Problem: Missing packet
- Actions taken:
 1. Update the status of the metavariable representing the missing packet to become “Optional”
 2. Add transitivity constraints involving the time variable of this packet.

ADIOP – The big picture (Three Modules)



ADIOP – The big picture (Four modules)





Motivations

- Debugging models of Interoperability test cases
 - Detect and debug inconsistencies in CSP models built by testers
 - Provide a framework for model acquisition and debugging
 - Enhance test cases correctness and completeness
 - Provide a user friendly interface for retrieving similar cases and updating CSP models
 - Interact with testers to insure consistency of model updates.
 - Integrate easily with the CSP framework including its modeling language
- Improving explanations
 - Retrieve similar past occurrences to solve new problems and provide useful explanation when diagnosis fails

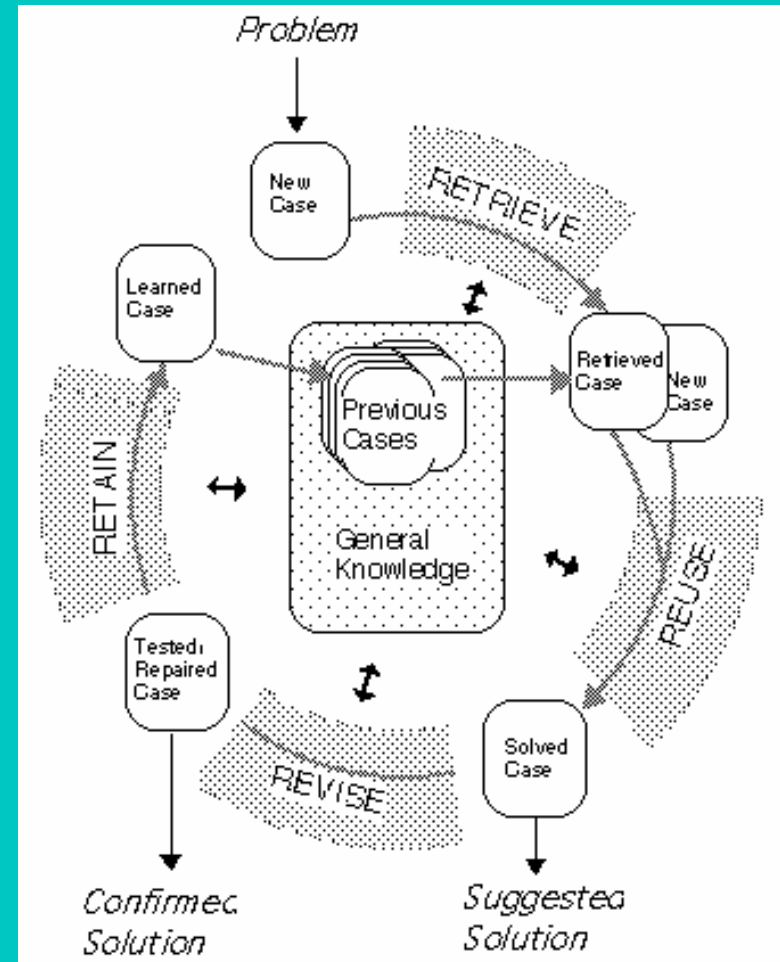


Incompleteness and Incorrectness (Sqalli & Freuder 1998)

- Human errors in writing the protocol specification
- Inconsistencies in different sections of the same specification
- The protocol specification is not well defined, and may be interpreted incorrectly when developing test suites
- Interactions with the external world are unknown
- Modeling of test cases is done by testers and may contain inconsistencies

Case-Based Reasoning

- CBR uses past experience to solve new problems. It is useful because: (Leake 1996)
 - similar problems tend to have similar solutions
 - same types of problems tend to recur
- CBR is a cyclical process comprised of four REs: (Aamodt & Plaza 1994)
 - Retrieve the most similar case(s)
 - Reuse the case(s) to solve the problem
 - Revise the proposed solution if necessary
 - Retain the new solution as a new case



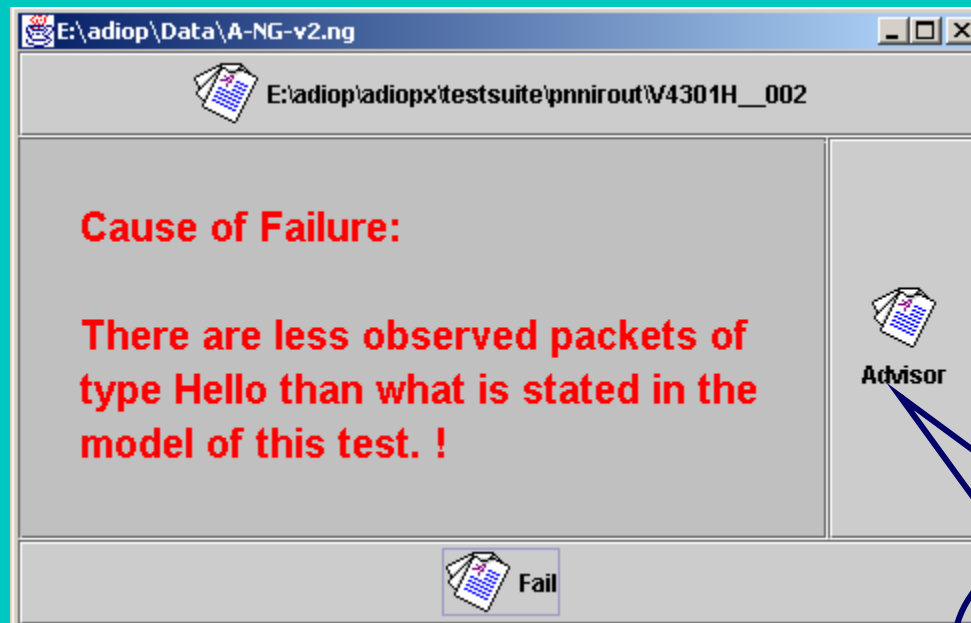


CBR System in ADIOP

- Case base storage: flat-record style database
- Case representation: 14 features (attribute-value pairs) including one for model update
- Case retrieval:
 - Semantical (1 feature) and syntactical similarity measures for computing distances between features.
 - N-grams are used for syntactical similarity
 - Weights are based on empirical data
 - Global similarity is computed using a nearest neighbor retrieval equation
- Case Reuse and Adaptation: basic rules for adaptation, and the tester confirms the adaptation results
- Case revision: is done manually by testers to finalize outcome
- Case Retention: the case is eventually stored in the case base (70% threshold is used)

Test Case failure

- CSP/CBR integration is used when a test case fails.



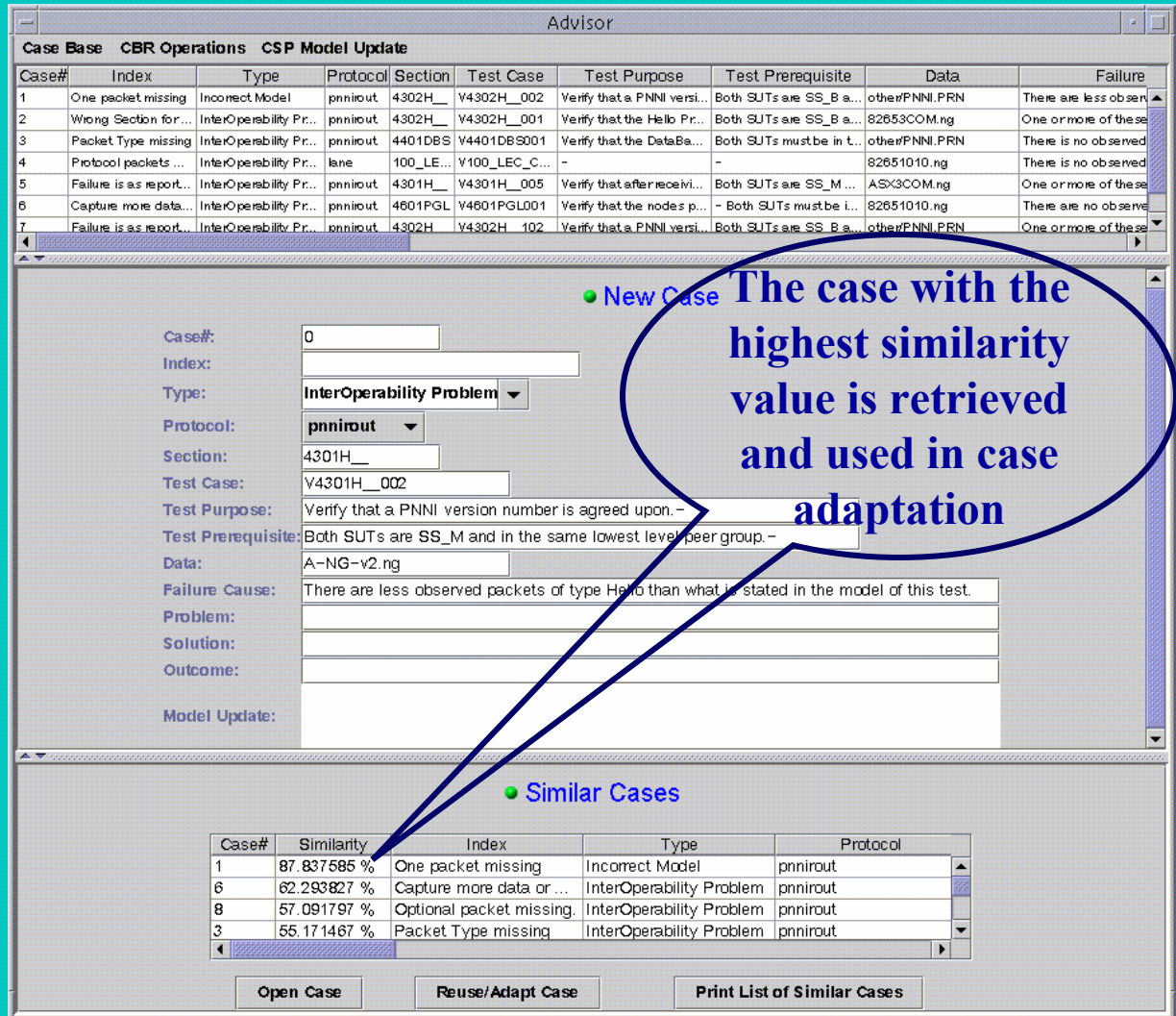
**CSP/CBR
component
of ADIOP**

Advisor

Panel showing all cases stored in the ADIOP's case base

Panel showing the new case with all 14 features

Panel showing all cases ranked by similarity to the new case



Case Base

| Case# | Index | Type | Protocol | Section | Test Case | Test Purpose | Test Prerequisite | Data | Failure |
|-------|-------------------------|------------------------|----------|-----------|---------------|------------------------------|---------------------------|----------------|-------------------------|
| 1 | One packet missing | Incorrect Model | pnriout | 4302H_ | V4302H__002 | Verify that a PNNI versi... | Both SUTs are SS_B a... | other/PNNI.PRN | There are less obser... |
| 2 | Wrong Section for ... | InterOperability Pr... | pnriout | 4302H_ | V4302H__001 | Verify that the Hello Pr... | Both SUTs are SS_B a... | 82653COM.ng | One or more of these |
| 3 | Packet Type missing | InterOperability Pr... | pnriout | 4401DBS | V4401DBS001 | Verify that the DataBa... | Both SUTs must be in t... | other/PNNI.PRN | There is no observed |
| 4 | Protocol packets ... | InterOperability Pr... | lane | 100_LE... | V100_LEC_C... | - | - | 82651010.ng | There is no observed |
| 5 | Failure is as report... | InterOperability Pr... | pnriout | 4301H_ | V4301H__005 | Verify that after receivi... | Both SUTs are SS_M ... | ASX3COM.ng | One or more of these |
| 6 | Capture more data... | InterOperability Pr... | pnriout | 4601PGL | V4601PGL001 | Verify that the nodes p... | - Both SUTs must be l... | 82651010.ng | There are no observe |
| 7 | Failure is as report... | InterOperability Pr... | pnriout | 4302H_ | V4302H__102 | Verify that a PNNI versi... | Both SUTs are SS_B a... | other/PNNI.PRN | One or more of these |

New Case

Case#: 0
 Index:
 Type: InterOperability Problem
 Protocol: pnriout
 Section: 4301H_
 Test Case: V4301H__002
 Test Purpose: Verify that a PNNI version number is agreed upon.-
 Test Prerequisite: Both SUTs are SS_M and in the same lowest level peer group.-
 Data: A-NG-v2.ng
 Failure Cause: There are less observed packets of type Hello than what is stated in the model of this test.
 Problem:
 Solution:
 Outcome:
 Model Update:

Similar Cases

| Case# | Similarity | Index | Type | Protocol |
|-------|-------------|--------------------------|--------------------------|----------|
| 1 | 87.837585 % | One packet missing | Incorrect Model | pnriout |
| 6 | 62.293827 % | Capture more data or ... | InterOperability Problem | pnriout |
| 8 | 57.091797 % | Optional packet missing. | InterOperability Problem | pnriout |
| 3 | 55.171467 % | Packet Type missing | InterOperability Problem | pnriout |

Buttons: Open Case, Reuse/Adapt Case, Print List of Similar Cases

Adaptation and Revised Case

Case Adaptation

| General Case Base Operations | | | | | |
|------------------------------|---|---|------------|-------------|---|
| Feature | New Case | Similar Case | Similarity | Weight | Adapted Case |
| Case# | 0 | 1 | 0.0 | 0 | SimCaseNum: 1 |
| Index | | One packet missing | 0.0 | 0 | One packet missing |
| Type | Incorrect Model | Incorrect Model | 100.0 | 1 | Incorrect Model |
| Protocol | pnniout | pnniout | 100.0 | 3 | pnniout |
| Section | 4301H__ | 4302H__ | 57.14286 | 0 | 4301H__ |
| Test Case | V4301H__002 | V4302H__002 | 72.72727 | 3 | V4301H__002 |
| Test Purpose | Verify that a PNNI version number is agreed u... | Verify that a PNNI version number is agreed u... | 100.0 | 3 | Verify that a PNNI version number is agreed u... |
| Test Prerequisite | Both SUTs are SS_M and in the same lowest l... | Both SUTs are SS_B and in different lowest le... | 74.61258 | 3 | Both SUTs are SS_M and in the same lowes... |
| Data | A-NG-v2.ng | otherPNNI.PRN | 0.0 | 1 | A-NG-v2.ng |
| Failure Cause | There are less observed packets of type Hello ... | There are less observed packets of type Hello ... | 100.0 | 15 | There are less observed packets of type Hello ... |
| Problem | | The second Hello packet (Hello1B) is missing | 0.0 | 0 | The second Hello packet (Hello1B) is missing |
| Solution | | The second Hello packet (Hello1B) is made opt... | 0.0 | 0 | The second Hello packet (Hello1B) is made opt... |
| Outcome | | Model updated, Warning added, interoperabl... | 0.0 | 0 | Model updated, Warning added, interperabl... |
| Model Update | | [ADD: \$UNARY_CONSTRAINT Hello1B.status ... | 0.0 | 0 | [ADD: \$UNARY_CONSTRAINT Hello1B.status ... |
| Total | | | | 91.104126 % | |

New case content can be modified by testers

Adapted case is generated by Advisor using new and similar case

Advisor computes the new similarity value and update the Adapted case content

Case is revised by testers

• New Case

Case#: SimCaseNum: 1

Index: One packet missing

Type: Incorrect Model

Protocol: pnniout

Section: 4301H__

Test Case: V4301H__002

Test Purpose: Verify that a PNNI version number is agreed upon.-

Test Prerequisite: Both SUTs are SS_M and in the same lowest level peer group.-

Data: A-NG-v2.ng

Failure Cause: There are less observed packets of type Hello than what is stated in the model of this test.

Problem: The second Hello packet (Hello1B) is missing

Solution: The second Hello packet (Hello1B) is made optional

Outcome: Model updated, Warning added, interoperable but not conformant

Model Update:

ADD: \$UNARY_CONSTRAINT Hello1B.status == D_Optional

ADD: \$BINARY_CONSTRAINT Hello1A.time <= Hello2A.time

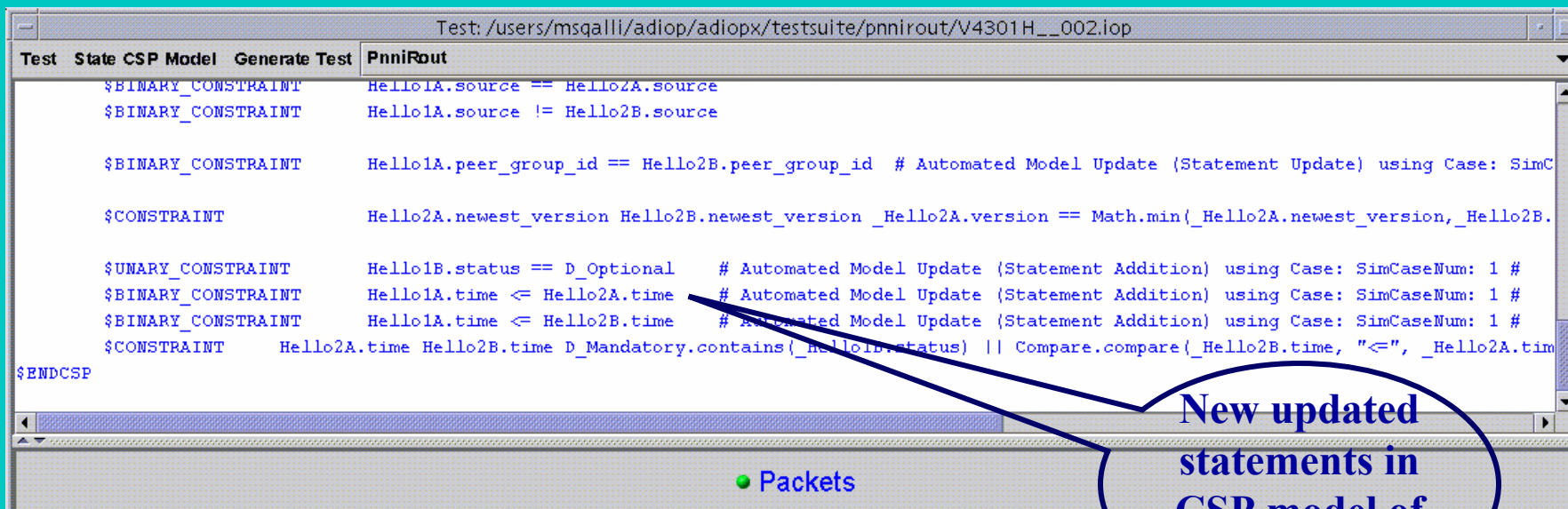
ADD: \$BINARY_CONSTRAINT Hello1A.time <= Hello2B.time

UPD: Hello1B.peer_group_id Hello2B.peer_group_id

ADD: \$CONSTRAINT Hello2A.time Hello2B.time D_Mandatory.contains(_Hello1B.status) || Compare.compare(_Hello

Updating CSP Models

- Functionality to update models is stored in the “Update Model” feature of cases.
- Language integrates with CSP modeling:
 - ADD, DEL, UPD



```

Test: /users/msqalli/adiop/adiopx/testsuite/pnnirout/V4301H__002.iop
Test State CSP Model Generate Test PnniRout
$BINARY_CONSTRAINT Hello1A.source == Hello2A.source
$BINARY_CONSTRAINT Hello1A.source != Hello2B.source

$BINARY_CONSTRAINT Hello1A.peer_group_id == Hello2B.peer_group_id # Automated Model Update (Statement Update) using Case: SimC
$CONSTRAINT Hello2A.newest_version Hello2B.newest_version _Hello2A.version == Math.min(_Hello2A.newest_version, _Hello2B.

$UNARY_CONSTRAINT Hello1B.status == D_Optional # Automated Model Update (Statement Addition) using Case: SimCaseNum: 1 #
$BINARY_CONSTRAINT Hello1A.time <= Hello2A.time # Automated Model Update (Statement Addition) using Case: SimCaseNum: 1 #
$BINARY_CONSTRAINT Hello1A.time <= Hello2B.time # Automated Model Update (Statement Addition) using Case: SimCaseNum: 1 #
$CONSTRAINT Hello2A.time Hello2B.time D_Mandatory.contains(_Hello1B.status) || Compare.compare(_Hello2B.time, "<=", _Hello2A.tim
$ENDCSP
  
```

New updated statements in CSP model of this test case

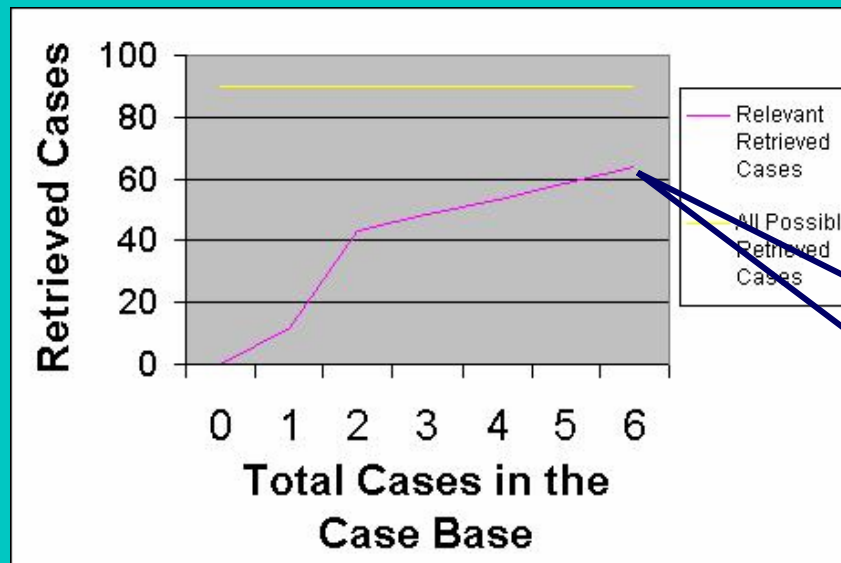


Improving Explanations

- Incorrect models generate incorrect explanations
- If inference does not lead to an explanation, the explanation provided by search in case of failure contains the violated constraints and is not useful
- The explanation provided by Diagnosis may be incomplete when only the problem is diagnosed. Cases can store information about how to resolve the interoperability problem found.
- Advisor provides useful explanations in these cases by retrieving similar previous situations.

Evaluation – Debugging

- 10 real-world captured data were used from two protocols
- Run only test cases that belong to the protocol used
- 90 test cases executed
- 6 cases stored in the case base (1 case for debugging models)
- These test cases were run using 1 case, 2 cases, and 6 cases



**In 64 test cases
out of 90, ADIOP
retrieved
relevant cases**



Evaluation – Debugging

- CBR System
 - Recall = 88%, Precision = 71%
 - Similarity measure is off by 10%
- Learning
 - Out of 54 test cases with non-useful explanation using diagnosis, 33 can be explained using Advisor, an improvement of more than 60%
- Model Updates
 - Case 1 was used to update CSP models of 12 test cases



Related work – CSP/CBR integration

- CSP supports CBR:
 - Case adaptation: (Purvis & Pu 1995) and (Lee et al. 1997).
 - Case retrieval: (Bilgic & Fox 1996).
- CBR supports MBR:
 - (Portinale & Torasso 1995)
 - (Van Someren, Surma & Torasso 1997)
 - (Karamouzis & Feyock 1992) where CBR/MBR integration enhances MBR by the CBR capacity to contribute new links into the causality model.
- In ADIOP,
 - CBR supports CSP by debugging models, and CBR accounts for errors in CSP models of test cases.
 - CBR improves on the explanation of CSP diagnosis.
 - The case feature for model update is formalized as a CSP. Thus, case representation uses CSP.



Summary

- CBR is used to debug and update CSP models and compensate for incompleteness and incorrectness
- Cases include information about updating CSP models using a similar language to the CSP modeling language
- CBR improves on problem diagnosis and explanation provided by CSP
- CSP models of interoperability test cases are used as the baseline and cases provide an addition to models for capturing new experiences

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Discussion